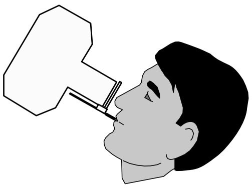
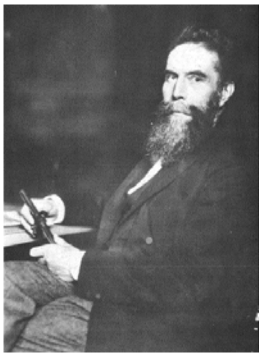
Production of X-Rays



History



Wilhelm
Conrad
Roentgen

Discovered
x-rays on
Nov. 8, 1895

Dr. Otto Walkhoff

First Dental Radiograph

25-minute exposure

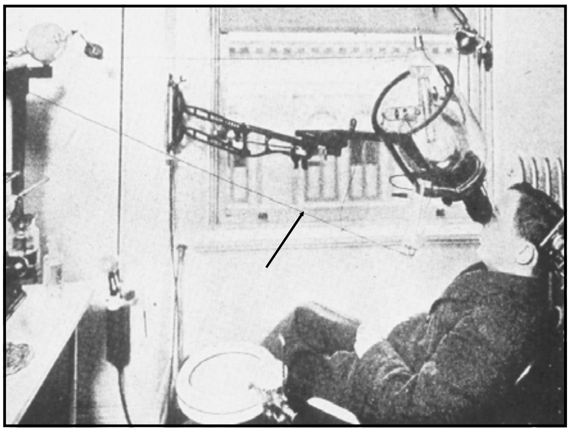
(< 0.5 seconds today)

before exposure

after exposure

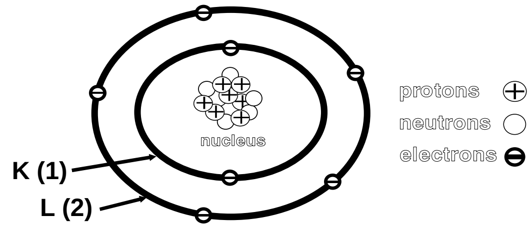
Dr. C. Edmund Kells

First Intraoral Radiograph
1896



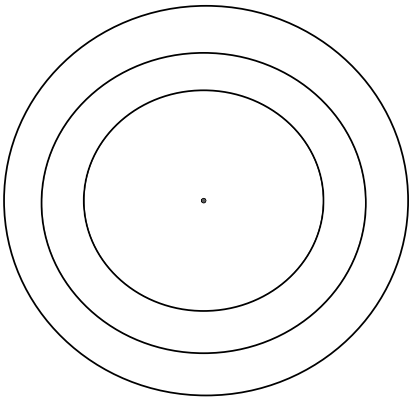
X-ray Physics

Atom (electrically neutral)



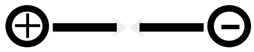
(M=3, N=4, etc.)

Atomic Number (Z) = # of protons



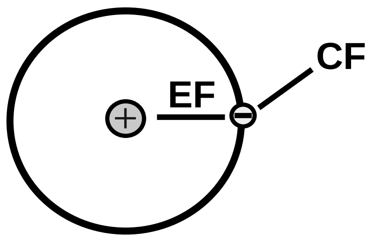
ELECTROSTATIC FORCE

Attraction between protons and electrons



CENTRIFUGAL FORCE

Pulls electrons away from nucleus



Balance between electrostatic force and centrifugal force keeps electrons in orbit around nucleus

Binding Energy

The amount of energy required to remove an electron from its orbit (= electrostatic force). Depends on atomic number (# of protons).

Electromagnetic Radiation

The movement of energy through space as a combination of electric and magnetic fields

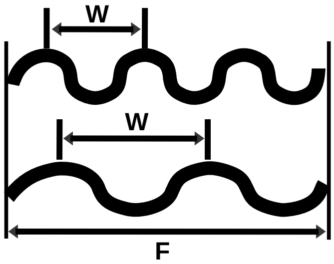
Travel at the speed of light

(3 x 10^8 meters/second)

(186,000 miles/second)

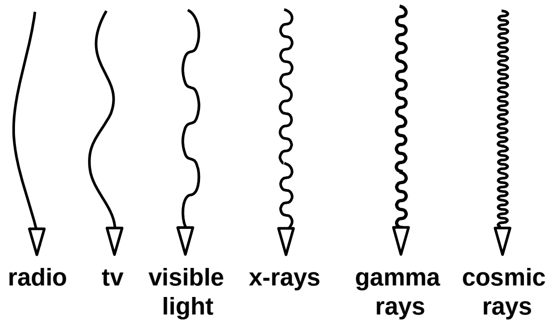
Electromagnetic Radiation

- X-ray
- Visible light
- Gamma ray
- TV waves
- Microwaves
- Radio waves



Wavelength x Frequency = Speed of light

Electromagnetic Spectrum

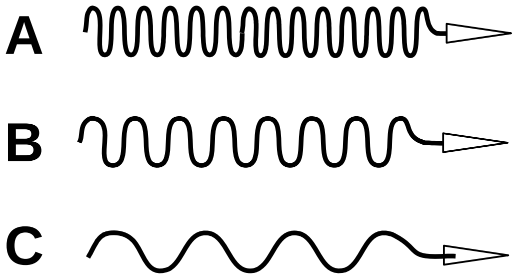


ENERGY

Ability to penetrate

Shorter wavelength, higher energy

Higher frequency, higher energy



X-ray Characteristics

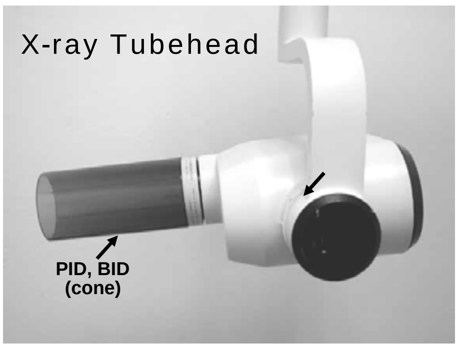
- High energy waves
- No mass
- No charge (neutral)
- Travel at speed of light
- Invisible

X-ray Characteristics

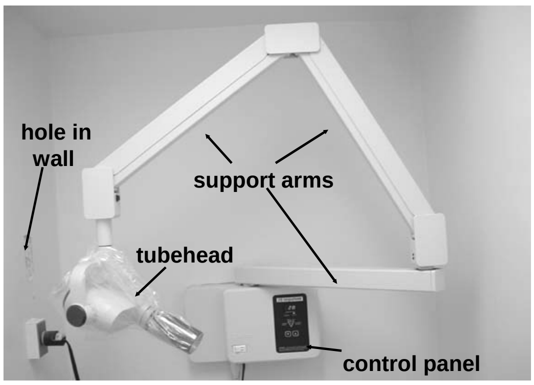
- Travel in straight line
- Cannot be focused to a point
- Differentially absorbed
- Cause fluorescence
- Harmful to living tissue

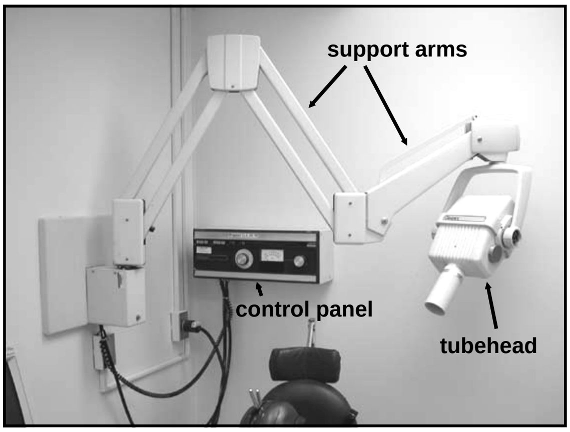
X-ray Machine

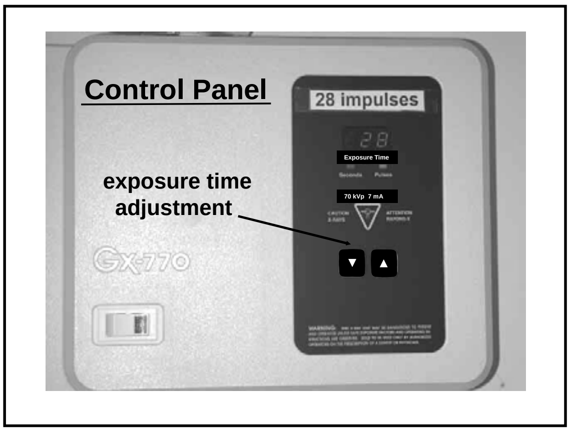
Tubehead
Support arms
Control panel

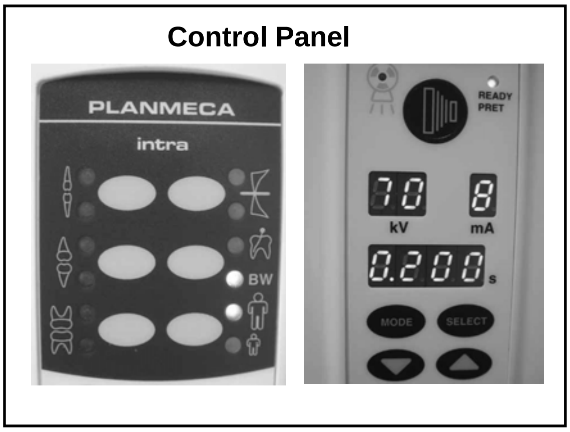


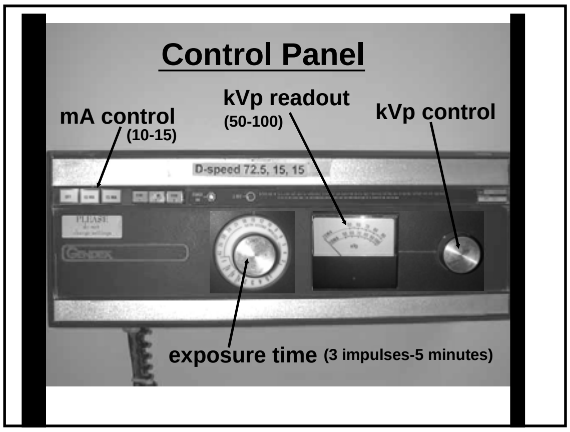
PID = position indicating device
BID = beam indicating device

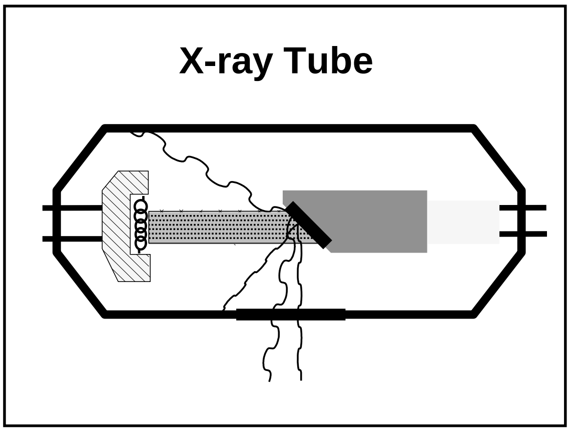


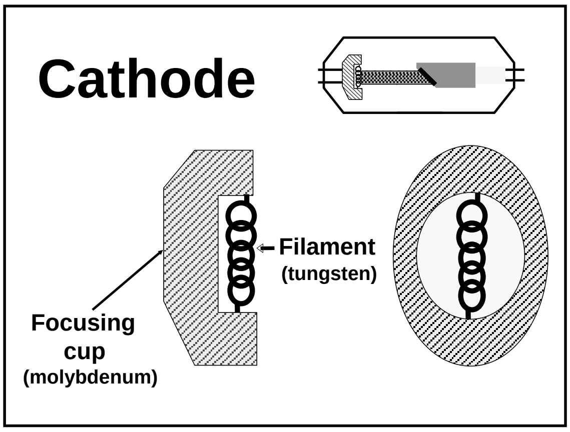

support arms
control panel
tubehead


Control Panel
28 impulses
exposure time
adjustment
Exposure Time
70 kVp 7 mA
GX-770


Control Panel
PLANMECA
intra
BW
READY
PRET
70
8
kV
mA
0.200 s
MODE
SELECT

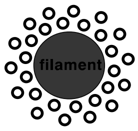

Control Panel
mA control
(10-15)
kVp readout
(50-100)
kVp control
D-speed 72.5, 15, 15
exposure time (3 impulses-5 minutes)


X-ray Tube


Cathode
Filament
(tungsten)
Focusing
cup
(molybdenum)

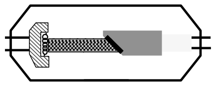
Thermionic Emission

Release of electrons from hot filament

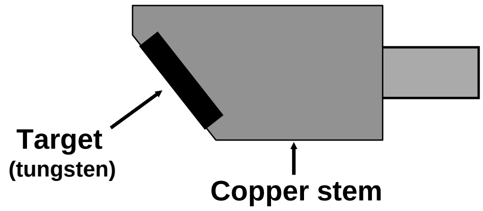


Increase current, increase heat
Increase heat, increase # electrons

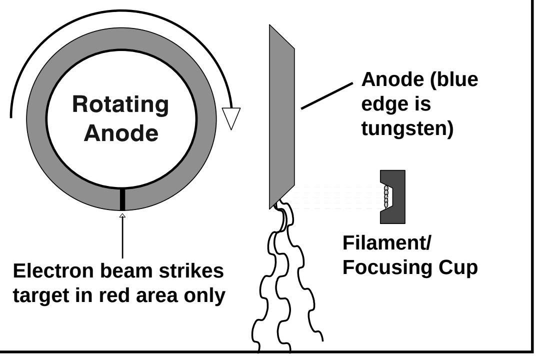
Anode



Dental x-ray machines have stationary anode



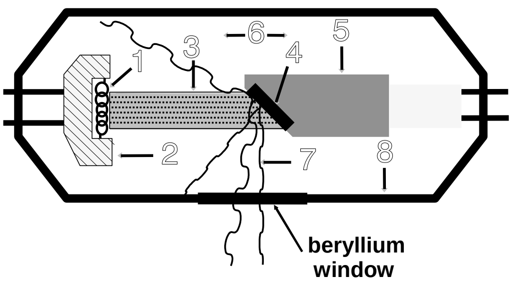
Medical Radiography

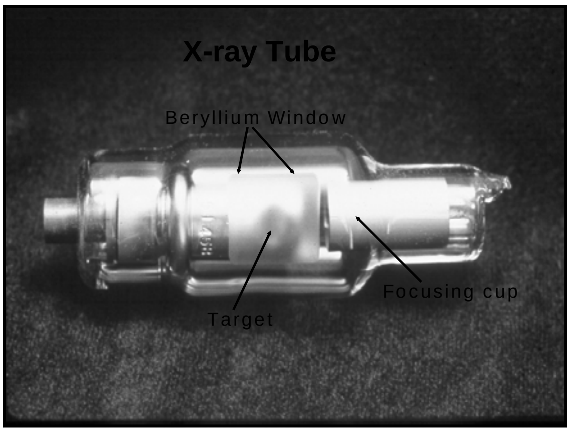


Tungsten
(Filament and Target)

- High atomic number (Z=74)
- Transfers heat readily
- High melting point (3370º C)
- Can be drawn into fine wire

X-ray Tube Components

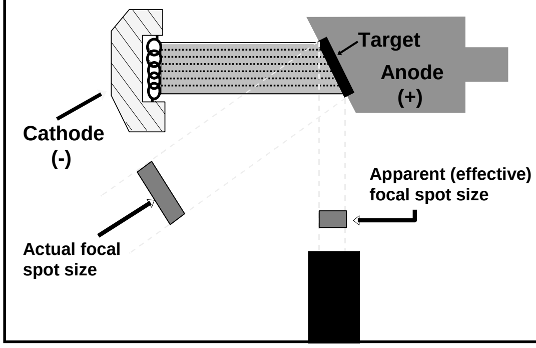




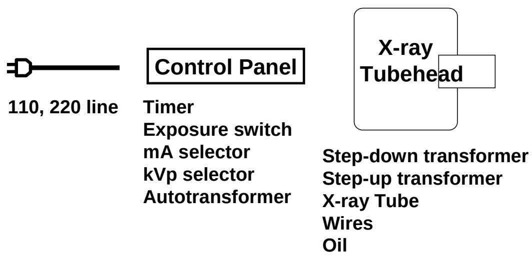
The smaller the focal spot (target), the sharper the image (teeth) will be.

During x-ray production, a lot of heat is generated. If the target is too small, it will overheat and burn up.

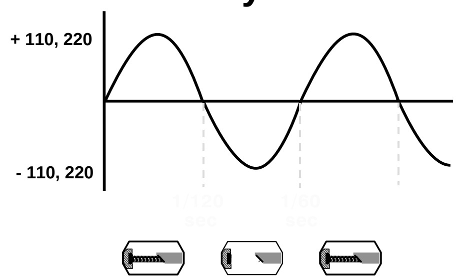
Line Focus Principle

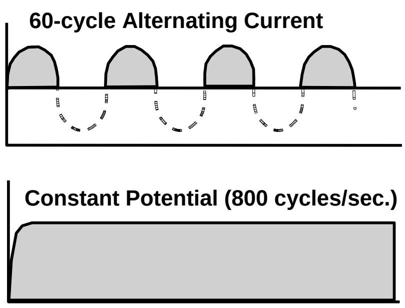


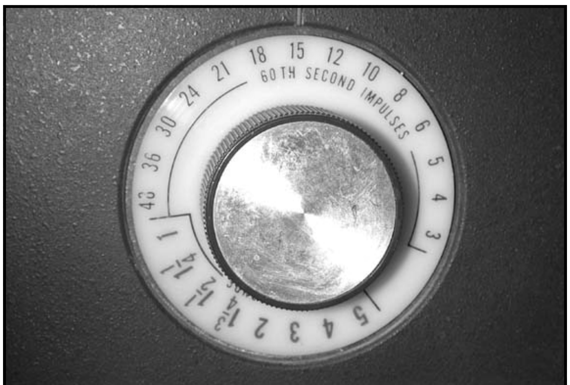
X-ray Machine Components



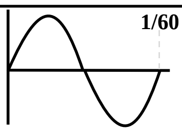
60-cycle AC







Timer

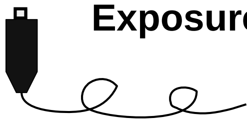


$$\frac{\text{Number of Impulses}}{60} = \text{Seconds}$$

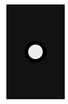
60 impulses/60 = 1 second

30 impulses/60 = 0.5 second

15 impulses/60 = 0.25 second

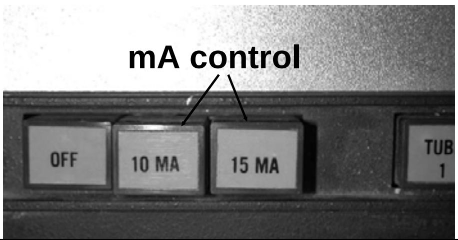


Exposure Switch



Allows current to flow to complete high and low voltage circuits.

You cannot overexpose by holding the exposure switch down too long!



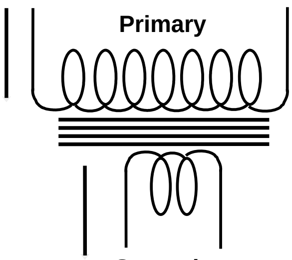
[redacted]

Step-Down Transformer

220 volt ⟶ 3 – 5 volts

Filament Circuit

Step-Down Transformer



[redacted]

[redacted]

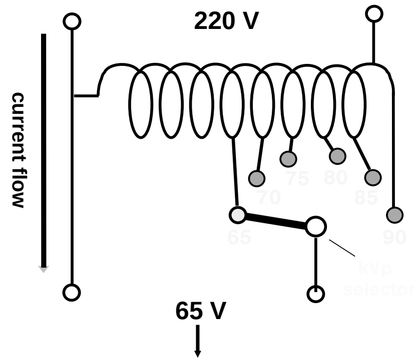
Autotransformer

Controls voltage between anode and cathode

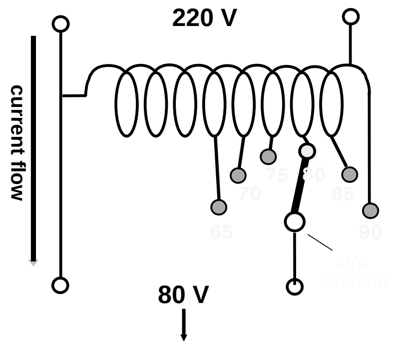
Regulated by kVp selector

(Similar to a rheostat)

Autotransformer



Autotransformer



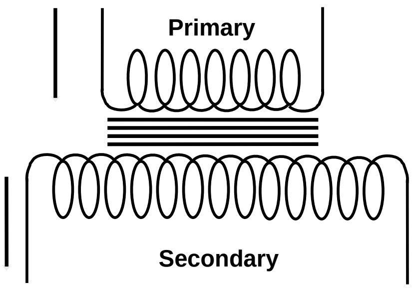
Step-Up Transformer

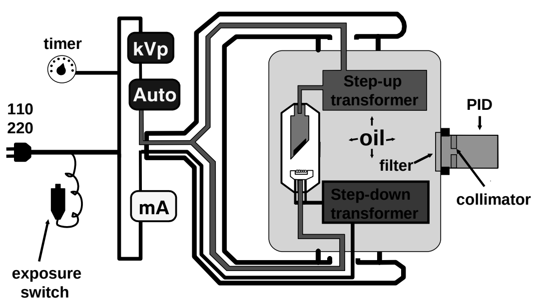
65 - 90 V ⟶ 65,000 - 90,000 V

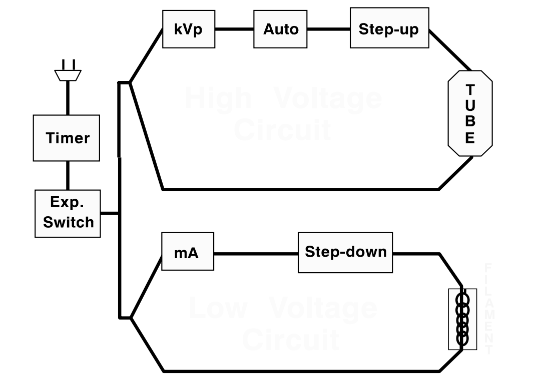
(65 kVp - 90 kVp)

kVp = kiloVoltage peak

Step-Up Transformer



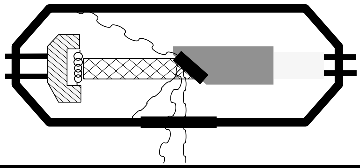




X-ray Production

Bremmstrahlung

Characteristic

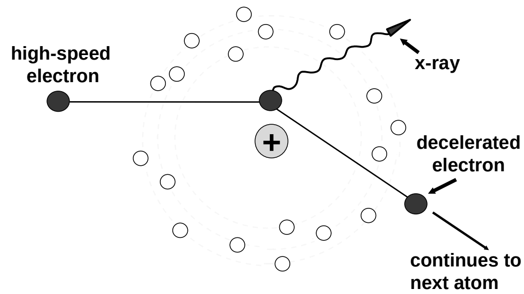


Bremsstrahlung Radiation

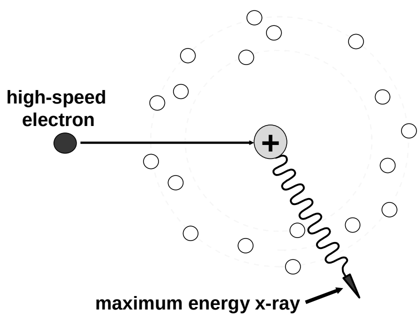
(Braking radiation, general radiation)

X-rays produced when high-speed electrons from the filament are slowed down as they pass close to, or strike, the nuclei of the target atoms

Bremsstrahlung X-ray Production



Bremsstrahlung X-ray Production Maximum energy



Characteristic Radiation

X-rays have energies characteristic of the target material (energy = difference between binding energies of target electrons involved, e.g., K & L, K & M, etc.)

The energy of the high-speed electron from the filament must be higher than the binding energy of the target electron with which it interacts in order to eject the target electron

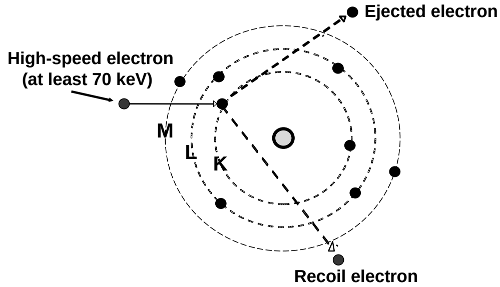
Tungsten

K-shell binding energy = 70 keV

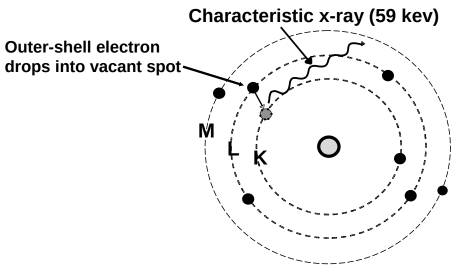
L-shell binding energy = 11 keV

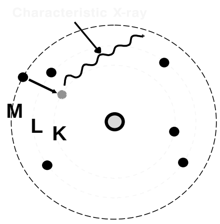
M-shell binding energy = 3 keV

Characteristic X-ray Production

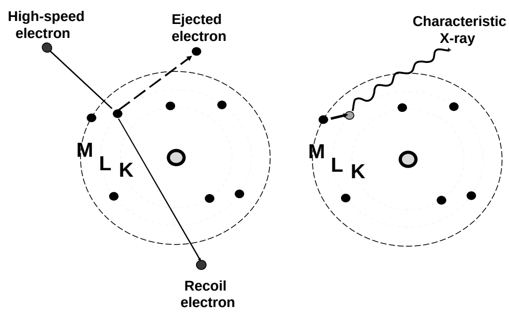


Characteristic X-ray Production





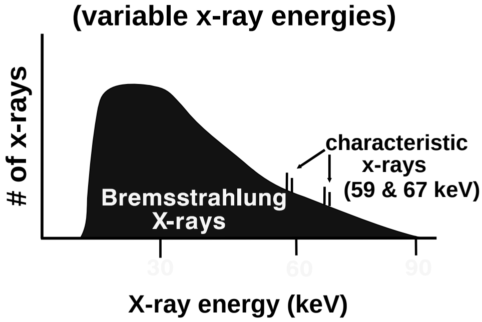
What is the energy of the characteristic x-ray produced? (M-shell binding energy = 3 keV)



What is the energy of the characteristic x-ray produced above?

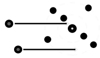
X-ray Spectrum

(variable x-ray energies)

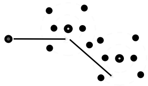


X-ray Spectrum results from:

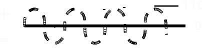
Varying electron/nucleus distances

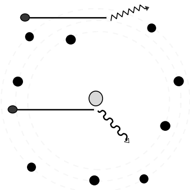


Multiple electron interactions



Varying voltage (AC)





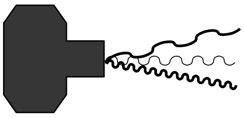
Electron interactions with target atoms

1 % produce x-rays

99 % produce heat

The excess heat is controlled by high melting point of tungsten, conductive properties of copper sleeve, and cooling from oil surrounding x-ray tube

X-ray Beam Modifiers

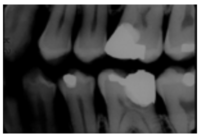


Exposure Factors

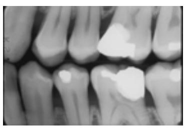
kVp

mA

Exposure time



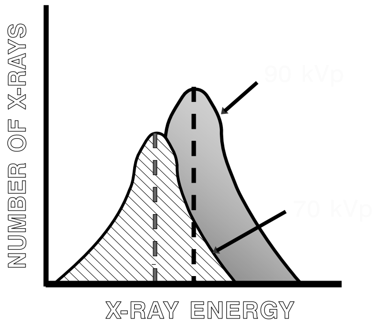
Incorrect exposure factors (too dark)



Correct exposure factors

Incorrect exposure factors (too light)

kVp (kiloVolt peak)

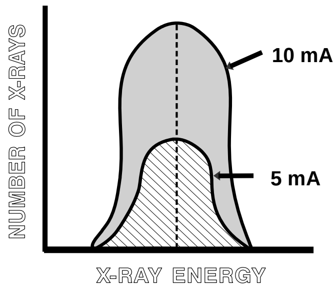


Increasing kVp results in:

- Higher average energy of x-rays
- Greater maximum energy x-rays
- More x-rays

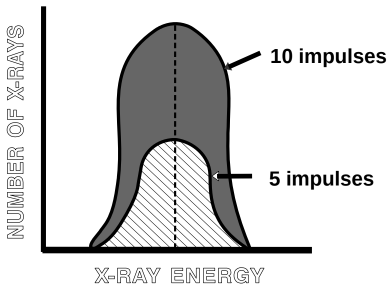
mA (milliampere)

(kVp, exposure time constant)



Exposure time

(kVp, mA constant)



Increasing mA or Exposure Time results in:

An increase in the number of x-rays produced

No change in the energy of the x-ray beam

mAs or mAi

milliamperes (mA) x seconds (s)

milliamperes (mA) x impulses (i)

60 impulses = 1 second

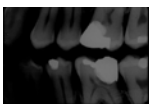
10 mA x .5 seconds = 5 mAs
20 mA x .25 seconds = 5 mAs

mAi = 60 x mAs

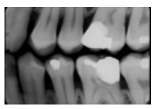
Constant patient size

1. Proper kVp, mA, exposure time (e.t.)	B
2. Increase mA; no change in kVp, e.t.	A
3. Decrease e.t.; no change in kVp, mA	C
4. Increase kVp; no change in mA, e.t.	A
5. Double mA, halve e.t.; no change in kVp	B

A



B

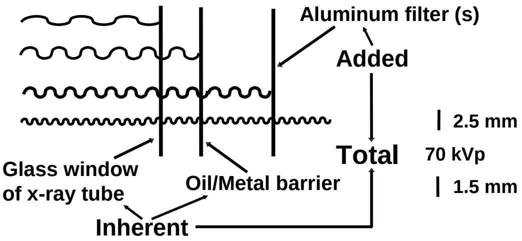


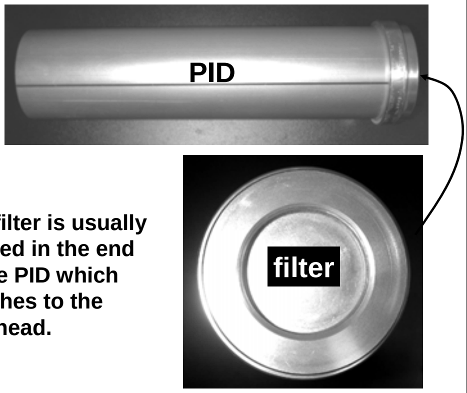
C

Filtration

The process of removing low-energy x-rays from the x-ray beam

Total Filtration





The filter is usually located in the end of the PID which attaches to the tubehead.

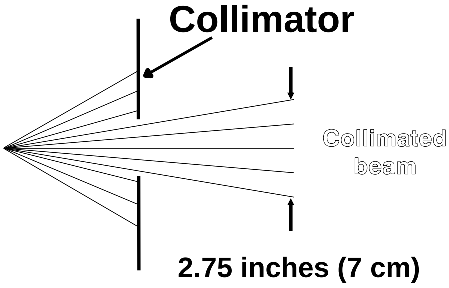
Collimation

Regulates the size and/or shape of the x-ray beam

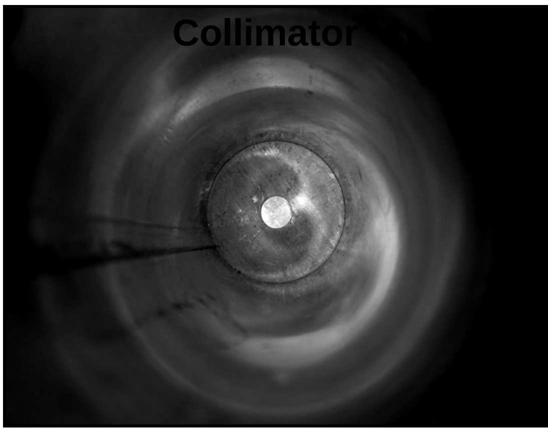
↓ area covered (less patient exposure)

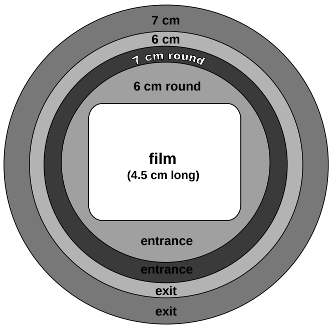
↓ scatter radiation

Collimator



2.75 inches (7 cm)
(maximum diameter at end of PID)





If you switch from a 7 cm round PID to a 6 cm round PID, the patient receives 25% less radiation.

Quality

average energy

Quantity

number of x-rays

	Quality	vs.	Quantity
kVp	↑ (1^0)		↑ (2^0)
mA	No change		↑
Time	No change		↑
Filtration	↑		↓

Half-Value Layer

Indicates the quality (energy) of the x-ray beam

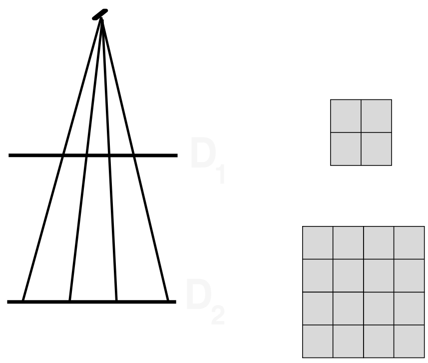
The thickness of aluminum needed to reduce the number of x-rays by one-half

2.5 - 70 kVp+; 1.5 < 70 kVp

INVERSE SQUARE LAW

The intensity of radiation varies inversely as the square of the target * -film distance

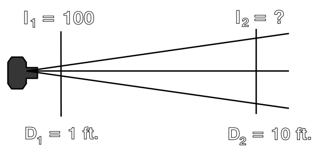
* target = source, focal spot, focus



$$\left(\frac{D_{KI}}{D_{UI}}\right)^2 \times KI = UI$$

D = distance
KI = known intensity
UI = unknown intensity

Inverse Square Law



$$\left(\frac{D_{KI}}{D_{UI}}\right)^2 \times KI = UI$$

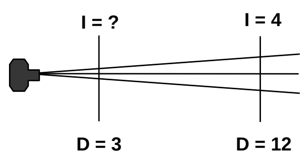
$$\left(\frac{1}{10}\right)^2 = \frac{1}{100}$$

$$\frac{1}{100} \times 100 = 1$$

1. **Divide <u>distance 1</u> (known intensity) by <u>distance 2</u> (unknown intensity)**
2. **Square this number**
3. **Multiply this number by the known intensity**

   This will equal the intensity at distance II

If the intensity of an x-ray beam is 4 at 12 feet, what is the intensity of the x-ray beam at 3 feet?



(I) at 12 ft. = 4 (I) at 3 ft. =?

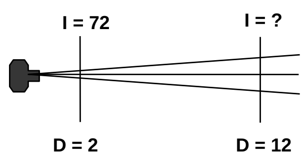
12 ÷3 =4

$$\left(\frac{D_{KI}}{D_{UI}}\right)^2 \times KI = UI$$

4 squared =16

16 X 4 = 64 (Intensity at 3 feet)

If the intensity of an x-ray beam is 72 at 2 feet, what is the intensity of the x-ray beam at 12 feet?



(I) at 2 ft. =72 (I) at 12 ft. = ?

2 ÷12 =1/6 $\left(\frac{D_{KI}}{D_{UI}}\right)^2 \times KI = UI$

1/6 squared = 1/36

1/36 X 72 = 2 (Intensity at 12 feet)